Thinking locally: exploring the importance of a subsidiary-centered model of FDI-related spillovers in Brazil

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Exploring the importance of a subsidiary-centered model of FDI-related spillovers in Brazil[1]

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Abstract

This paper investigates FDI-related spillovers in Brazil for the period 1996-2005. In contrast to most previous recent studies, which have failed to identify any significant effects in emerging economies, we found that horizontal spillovers did arise in Brazil. However, they did not arise simply as a consequence of general FDI-mediated technology transfer from MNC headquarters, as the standard approach presumes. Nor were they associated with expected inter-industry differences in technological intensity, or with differences in domestic firms' absorptive capability. Instead, spillovers were associated with the existence of particular kinds of localized knowledge-creation activities undertaken by subsidiaries. We discuss the theory and policy implications that emerge from these results.

Keywords

FDI spillovers; subsidiaries; heterogeneity; localized innovation; Brazil; productivity.

JEL codes

O3, O4, O1

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1. Introduction

Multinational corporations (MNCs) are without doubt the main drivers of innovation in most industries. When they set up a plant in a host country they are expected to bring not just employment and capital, but also new skills and technological knowledge. Such skills and knowledge are supposed to leak out from MNC subsidiaries to domestic firms creating what are known as 'spillover' effects. Yet the empirical evidence to support such effects, as expected by both policymakers and theorists, is often inconclusive and contradictory. Indeed, in more recent studies, both negative and insignificant effects are found to be as common as positive effects, and no convincing explanations are provided as to why this is the case (see Javorcik, 2004; Crespo and Fontoura, 2007). In this paper, we are able to identify significant positive results, in the case of Brazil, and to explain why such results emerge. This is because we incorporate the notion of technologically active subsidiaries in the model of spillover generation.

The standard approach used to explore the possibility of spillover effects in association with MNCs' operations in host economies typically ignores the potential role of subsidiaries' own activities in the generation of spillover effects. Spillovers are presumed to arise as a result of technological assets created by, and decisions taken centrally within, MNCs (see, for example, Blomstrom and Person, 1983; Haddad and Harrison, 1993; Haskel *et al*., 2002; Javorcik, 2004; Girma, 2005; Chang and Xu, 2008). Subsidiaries are presumed to be passive in this process, acting merely as a leaky, late-stage section of the conduit between knowledge creation in the parent company and its absorption (or not) by domestic firms in the host economy.

In this paper, following on from previous work by Marin and Bell (2006) and Marin and Sasidharan (2008), we explore an alternative approach; a subsidiary-centered approach. In this

approach, a substantial part of the technological potential for spillover effects in association with MNCs' operations is seen as arising within the local subsidiary as a result of its own knowledge-creating activities in the host country, rather than being delivered to it from the parent company. This perspective incorporates insights generated recently by the International Business (IB) literature, which has shown that subsidiaries might play active innovative roles in host economies, both in advanced countries (Pearce, 1999; Kuemmerle, 1999; Zander, 1999; Kumar, 2001), and in less advanced contexts (Ariffin and Bell, 1999; Marin and Bell, 2005; Ferigotti and Figueiredo, 2005; Giuliani and Marin, 2007).

We examine the importance of a subsidiary-centered perspective by exploring four models of FDI-related spillover effects. The first three reflect standard approaches to explaining the process of spillover generation; the fourth incorporates technologically active subsidiaries. In line with common practice, we model FDI spillovers within the familiar production function framework. However, our empirical analysis improves on the recent literature in several ways by taking into account some of the econometric problems rarely considered in earlier studies. We estimate horizontal spillovers. The estimation uses firm-level data provided by two surveys conducted by IBGE, the Brazilian statistical office: PIA, the Annual Industrial Survey: 1996-2005 and, PINTEC, the Innovation Survey covering 2003 and 2005.

The results of the study confirm our main hypothesis: significant spillover effects did arise in Brazil. However, they did not arise simply as a consequence of general FDI-mediated technology transfer from parent companies, as the standard approach to spillovers suggests. Nor were they associated with expected inter-industry differences in technological intensity, or with differences in the absorptive capability of domestic firms. Instead, they were associated with the existence of specific kinds of knowledge-creation activities undertaken by local subsidiaries in the host

economy themselves. These results point to the limitations of adopting an 'MNC-centered' perspective towards the process of spillover generation in association with MNCs, and highlight the potential of focusing on different aspects of subsidiary heterogeneity to explain both the sign and significance of any spillover effect in association with MNCs' operations in host countries.

The paper is organized as follows. Section 2 examines the conventional approaches used to explore the possibility of FDI-related spillover effects in host economies, and discusses the related problems. Section 3 discusses the relevance of a subsidiary-centered model of spillover effects. Section 4 outlines the context under study. Section 5 describes the data and the methodology. Section 6 analyzes our results and Section 7 concludes, with implications for theory and policy.

2. Centrally driven models of FDI spillovers

Following Hymer's view (1976) of the MNC and 'pioneer' studies of Caves (1974) and Globerman (1979), research on MNC-related spillovers in host economies has, for 40 years, largely adopted a 'centrally driven' perspective to explore the possibility of spillovers in connection with MNCs' operations. From this perspective, spillovers are expected to arise in association with technological assets and decisions taken centrally by MNCs. MNCs exist because they have been able to develop some kind of innovative, cost, financial or marketing advantage – known as 'ownership advantage'. Subsidiaries take on the role of exploiting this superior advantage in a particular context/country. They are supposed to own it, by definition, simply because they are part of the MNC, and because MNCs are supposed to be good at transferring knowledge. Thus, to the extent that knowledge displays some of the characteristics of a public good, it is expected that some of the knowledge that underlies the superior ownership

advantage of MNCs may diffuse from subsidiaries to domestic firms, generating spillover: (1) via the movement of highly skilled staff; (2) via demonstration effects; (3) via purposeful transfers of knowledge to local suppliers; and/or (4) via competition effects.

In exploring possible explanations for the absence of technology spillovers – the more common scenario found in the most recent studies[i] – the research has focused on two types of explanation. First, a **demand-side** explanation – on the side of the recipients, the domestic firms – where reasons for the absence of spillover effects are typically seen as lying in the inability of domestic firms to absorb the superior knowledge and skills that MNCs deliver to their subsidiaries (see, for instance, Kokko, 1994; Konings, 2001; Kinoshita, 2001; Castellani and Zanfei, 2005; Patibandla and Sanyal, 2005; Girma, 2005; Peri and Urban, 2006). Second, a **supply-side** explanation – on the side of the source of spillovers, the MNC – where reasons for the absence of spillover effects are explored in connection with the influence of various factors on MNCs' decisions about how much of which kinds of centrally created technology to transfer to subsidiaries, and how rapidly to do so. For instance, in relation to supply-side explanations, attention has been given to factors such as: (1) the industry in which MNCs operate – where MNCs operating in 'higher'-tech industries are associated with a higher potential for spillover effects since they are supposed to be more technologically intensive (Kathuria, 2001; Buckley, Clegg and Wang, 2006; Kokko, 1994; Alvarez and Molero, 2005); (2) the mode of entry of the MNC – where the use of majority ownership has been associated with a higher likelihood of positive spillover effects relative to minority ownership because it implies the transfer of more advanced technologies (Ramachandran, 1993); or (3) the motivation to conduct FDI – where FDI motivated by technology sourcing has been associated with less potential for spillover effects

than FDI motivated by technology exploiting because the former is supposed to imply less technology transfer (see, for instance, Girma, 2005; Driffield and Love, 2006[ii]).

Existing research, however, rarely considers another **supply side** explanation, namely differences in subsidiaries' own technological and other activities in the host economy[iii]. Subsidiaries are typically considered to be passive, or to play no role in the process of spillover generation. This is despite recent theorizing from the International Business literature which has convincingly shown that subsidiaries can be quite active, and that their own activities in the host economy play increasingly significant roles for both ***technology transfer*** and ***technology creation*** within MNCs. This is true not only for subsidiaries located in advanced countries (Kuemmerle, 1999; Kumar, 2001; Pearce, 1999; Zander, 1999), but also for those in less advanced contexts (Ariffin and Bell, 1999; Ferigotti and Figueiredo, 2005; Giuliani and Marin, 2007; Marin and Bell, 2005). These views are incorporated into the model of spillover generation proposed in the next section.

3. A 'subsidiary-centered' model of FDI-related spillovers

In our view, subsidiaries' own activities in the host economy are crucial to understanding the process of spillover generation in association with MNCs' operations for two main reasons. The first is that subsidiaries' own technological activities contribute to the absorptive capacity of the subsidiary with respect to the technology transferred from the parent, thereby increasing the potential of spillovers in association with knowledge created by the MNC in other locations. The second is that those localized technological activities of subsidiaries can become the source of more original technological knowledge, which can then spill over to domestic firms.

3.1 Localized knowledge activities of subsidiaries, absorptive capability and spillover effects

As suggested earlier, implicit in much of the spillovers literature is the assumption that knowledge is a kind of 'public good' within MNCs, i.e. that it can be almost automatically moved across different departments and branches within the MNC, or from headquarters to local subsidiaries. Several studies within the International Business (IB) literature, however, have demonstrated that this supposition is unrealistic (Teece, 1977; Szulansky, 1996; Gupta and Govindarajan, 2000). Teece (1977), for instance, explored 26 technology transfer projects within MNCs and demonstrated that the cost of technology transfer could reach as much as 59 percent of the total cost of transferring a project to a foreign country, and that the technological capacity of the recipient unit was the most important factor in reducing the cost and facilitating the transfer. Later on, pointing in the same direction, Ngoh (1994) and Lim (1991) showed that subsidiaries in the electronic sector in Malaysia struggled for many years and invested heavily in human resources to be able to absorb technology transferred from the parents (quoted by Hobday and Rush, 2007). Similar results were indicated by Szulansky (1996), Gupta and Govindarajan (2000) and Minbaeva, Pedersen, Bjorkman, Fey and Park (2003), in a number of studies on technology transfer within MNCs. All of them identified the recipient unit's lack of knowledge as the main barrier to internal knowledge transfer within MNCs.

In light of this evidence we hypothesize that technologically active subsidiaries, which invest resources in the development of their own technological capabilities in the host economy, are more likely than technologically passive subsidiaries to generate spillover effects of superior technological resources developed by their parents (and other subsidiaries) in other locations. This is because they will be more capable of absorbing these superior technological resources

that are supposedly available to them. Technologically passive subsidiaries, on the contrary, will be less likely to be able to absorb the superior technological resources developed by their parents in other locations in a timely manner and will, therefore, be less likely to generate spillover in association with these resources.

3.2 Localized innovative activity of subsidiaries, local innovation and spillover effects

For a long time the IB literature conceptualized subsidiaries as passive recipients of superior technological assets created by their parents. They were supposed to exist merely to exploit these unique technological assets in the host economy. Things have changed substantially, however, during the last three decades or so. With the diffusion of new technologies and organizational arrangements, as well as deep changes in worldwide competition, international business has become more about actively seeking advantages originating in the global spread of the firm, and less about exploiting centrally created technological assets (Kogut, 2002; Hedlund, 1986; Dunning, 1994; Cantwell and Sanna-Randaccio, 1993). The role of subsidiaries has therefore become more prominent. Drawing on their unique capacities and contextual resources, subsidiaries, are engaged more frequently than before in developing distinctive technological assets for the corporation (Birkinshaw and Hood, 1998). Furthermore, it is increasingly emphasized that their orientation toward developing unique assets does not always depend exclusively on headquarters' mandates (Birkinshaw and Hood, 1998). Instead, subsidiaries themselves are increasingly actively engaging in the attraction of capacities and resources from the rest of the corporation, as well as in the development of their own technological capabilities, in order to gain importance within their corporations (Birkinshaw, 1997; Birkinshaw *et al*., 1998; Cantwell and Janne, 1999; Birkinshaw *et al*., 2005).

In light of this evidence we hypothesize that technologically active subsidiaries, which invest in the development of their own technological capacity in the host economy, via, for instance, R&D or the use of highly skilled workers, are more likely than technologically passive ones to generate spillover effects of new knowledge. This is because they will be more likely to create new, unique assets, which would be valuable for domestic firms in the same contexts and would impact positively on their productivity if leakages occur.

4. The context: MNCs in Brazil

The solid and deep-rooted participation of MNC subsidiaries in the Brazilian economy makes it a very interesting case by which to investigate the relevance of the subsidiary-centered perspective in explaining FDI-related spillover effects. MNC subsidiaries rank amongst the major firms in Brazil, and contribute to significant shares of manufacturing value added, employment, exports and adoption of new technologies, among other indicators of economic dynamism. For instance, in a representative sample studied by Gonçalves (2005), MNC subsidiaries accounted for 57 percent of the turnover in the manufacturing industry as a whole in 2000. This share is much higher in particular sectors such as motor vehicles (98%), office machines (94%), and telecom equipments (88%) (Gonçalves, 2005:60).

Many of these subsidiaries arrived in Brazil in the 1950s and played a central role in the process of industrialization by import substitution, being key sources of capital for building production capacity and acting as channels for gaining access to international technologies (Costa, 2006)[iv].

The 1990s, however, represented an important quantitative and qualitative change for the foreign MNC subsidiaries' presence and activities in Brazil. In line with the global trend, this period was marked by broad(er) trade liberalization and stabilization of the Brazilian economy. In this

context, there was an upsurge of FDI inflows into the country – jumping from around US$ 1 billion in 1993 to US$ 32.8 billion in 2000[v], followed by an intensification of foreign MNCs' presence in the country. An important consequence of this was a competition shock, which forced companies located in the country – not only domestic ones but also foreign MNC subsidiaries – to react in order to defend their shares of the Brazilian market from imports and newcomers' subsidiaries (Costa, 2006). In fact, the evidence suggests that MNCs' subsidiaries were very active in the broad process of modernization of Brazilian industry, which led to gains in terms of product quality, productivity and efficiency.

However, the increased participation of MNCs' subsidiaries in the Brazilian economy raised concerns and fuelled debate about the implications of their strong presence. Many studies have analyzed the behavior and characteristics of MNCs' subsidiaries in the country, with particular attention being paid to issues related to innovation and technology (see, for instance, Cassiolato *et al*., 2001; Costa and Queiroz, 2002; Franco and Quadros, 2002). Yet, to the best of our knowledge, studies about the effects of MNCs' presence on the behavior and performance of domestic firms in Brazil are almost nonexistent; two exceptions are Gonçalves (2005) and de Araújo (2004). Our study extends beyond these two previous studies by exploring the role of subsidiaries' heterogeneity in technological spillovers in Brazil.

5. Methodology

5.1 Empirical strategy

We examine the importance of a subsidiary-centered perspective of the spillover process in Brazil by exploring four models of FDI-related spillover effects. The first three reflect standard approaches to explaining the process of spillover generation; the fourth incorporates

technologically active subsidiaries. More specifically, we explore: (1) a ***'Pipeline' model***: where spillover effects arise from MNCs independently of any other circumstance; (2) an ***'Absorptive Capability' model***: where *potential* spillover effects arise from MNCs, but are captured only by domestic firms with high absorptive capabilities; (3) an ***'Industry' model***: where spillovers arise only in the more 'advanced' or 'technologically intensive' industries; and (4) a ***'Subsidiary-Centered' model***: where spillover effects arise from MNCs only when subsidiaries are technologically active in the host country.

5.2 The data: the PINTEC innovation survey

The empirical analysis reported here uses information provided by two surveys conducted by IBGE (the Brazilian statistics office): (1) PIA – the Annual Industrial Survey (1996-2005), and (2) PINTEC - the Brazilian Innovation Survey (2003 and 2005). The sample of firms covered by PIA is representative and changes year by year. As a result, when merging PIA for the different years (10 years) we lost around 30% of the original samples; we were thus left with a sample of 10,152 firms. PINTEC is also representative, although it is based on a different sample of firms to PIA. As a consequence, when pooling PINTEC 2003 and 2005, we were left with a sample of 12,283 firms, 997 of which were subsidiaries. By pooling PINTEC (2003 and 2005) and PIA (1996-05) we were left with a sample of 4,526 manufacturing firms (548 MNC subsidiaries and 3,979 domestic firms).

PIA provides (directly or indirectly) basic economic firm-level data such as size, added value, sales, employment, total assets, investments, depreciation and so on. These variables permitted the computation of indicators used in the estimation of production functions (see Section 5.4). PINTEC provides information on technological activities at firm level, allowing the computation

of several measures of technological behavior for both MNC subsidiaries and domestic firms (see Section 5.3).

5.3 Measuring innovation activity of MNC subsidiaries and domestic firms

We compute three types of indicators of technological activity of subsidiaries and domestic firms, based on variables from PINTEC: (1) *investments in disembodied knowledge*, (2) *human capital* and (3) *investments in capital-embodied technology*. In order to control for size all the indicators are calculated as intensities with respect to total employees as of 31 December 2005[vi] (PIA question 4).

(1) *Investments in disembodied knowledge* are the efforts carried out by firms to acquire and/or develop (new) technological knowledge, which is not embodied in any kind of equipment, instruments, manual, patent, and so forth. In principle, these efforts could be potentially the most important sources of locally driven knowledge spillovers from subsidiaries to domestic firms since they cover the kinds of knowledge that are potentially most mobile and most likely to leak from subsidiaries. Four measures are used:

- intensity of expenditures on internal R&D (PINTEC 31) and external R&D (PINTEC 32);
- intensity of expenditures on other disembodied knowledge (PINTEC 33);
- intensity of expenditures on setting up innovation (PINTEC 37);
- intensity of expenditures on marketing/publicity (PIA, question 62).

(2) *Human capital* refers to measures to capture different intensities of human resources employed by firms, which in principle are capable of being oriented to monitoring, incorporating

and developing new technological knowledge. This indicator is complementary to R&D expenditures. Two indicators were calculated as measures of skill intensity:

- R&D staff – calculated as the number of PhDs, masters, graduates and technicians (full time equivalent) dedicated to R&D activities (PINTEC 46-49, 51-54) as a proportion of total employment; and
- expenditures on innovation-related training (PINTEC, 35).

(3) Finally, *investments in capital-embodied technology* refer to the efforts carried out by firms to introduce new technological knowledge embodied in capital goods. Although this kind of investment is likely to be a very important source of productivity growth in the investing firms, it does not seem likely to be a significant driver of 'genuine' spillovers to other firms. While information about the introduction of capital-embodied assets in one firm may leak to another, the knowledge actually embodied in those assets is probably much more 'sticky'. The indicator used here is: expenditures on machinery and equipment meant for innovation (PINTEC, question 34).

5.4 Estimating spillover effects

5.4.1 General framework for estimating spillover effects

Our estimation of spillover effects involves two steps. In the first step, we calculate the production functions per industry in order to obtain measures of total factor productivity (TFP) per industry. In the second, we relate TFP to proxies for FDI participation.

First step

To estimate TFP we use the semi-parametric approach suggested by Levinsohn and Petrin (2003), which corrects for endogeneity in the determination of inputs. This method allows for firm-specific productivity differences that exhibit idiosyncratic changes over time and thus addresses the simultaneity bias between productivity shocks and input choices (for a discussion of this, see Lenvinsohn and Petrin, 2003). The estimation is based on the following variables: Y^{d}ijt, real output of domestic firms *i*, operating in sector *j*, at time *t*; K^{d}_{ijt} is the value of fixed assets; L^{d}_{ijt} is expressed as efficiency units, calculated by dividing salaries and wages at firm level by the average wage rate of each firm's industry, and M^{d}_{ijt} is the value of materials. Nominal values are deflated using wholesale prices per industry obtained from the IBGE (Brazil).

Second step

In the second step we relate the two measures of TFP to proxies for foreign participation in the same five-digit industry.

$$\Delta \ln TFP^{d}{}_{ijt} = \alpha_0 + \alpha_1 \Delta FDIpart_{jt-1} + \alpha_3 \Delta Concentration_{jt} + \alpha_4 \Delta \mathrm{Im}\, ports_{jt} + I_j + T_t + \mu_{it} \qquad (1)$$

FDIpart measures the scale of MNCs' presence in each sub-industry *j* and is introduced lagged one period to capture spillover effects avoiding an identification problem. It is calculated as the share of total employment in the five-digit sub-industry *j* that is accounted by the employment of foreign-owned firms in that sub-industry[vii]. Very often studies on spillover effects have aggregated data at two digits (divisions). We work with FDI participation at five digits

(subclasses). This provides greater variability and increases the possibility of identifying the desired effects. We use two measures of FDI presence per industry: employment and output.

I and *T* are industry and time dummies. *Concentration* and *Import penetration* are control variables. These are introduced to capture changes in the unobservable variables that affect competition and which might have promoted greater efficiency in the domestic industry[viii].

Several other aspects of the estimation methods merit further comment. First, by using plant-level specification and modeling in first differences, we control for fixed differences in productivity levels across firms and industries that could affect the level of foreign investment. We thus address the identification problem highlighted by Aitken and Harrison (1999)[ix]. Second, this specification and the inclusion of industry and time dummies corrects for the omission of other unobservable variables that might undermine the relationship between FDI and productivity growth of domestic firms. In particular:

- the use of first differences removes plant-specific, industry and regional fixed effects such as firms' heterogeneous long-term strategies, and differences in the regional infrastructure and/or technological opportunity of industries[x];
- the use of industry dummies removes the fixed characteristics of domestic firms that belong to particular industries;
- the use of year dummies controls for economic-wide shocks.

Third, to take account of any potential correlation between the error terms for firms in the same industry, we clustered standard errors in industry-year combinations.

5.4.2 Exploring the 'absorptive capability', 'industry' and 'subsidiary-centered' models of spillover effects

The approach discussed previously is used to estimate spillovers in the pipeline model. To examine the importance of the other three models, we apply Equation (1) to particular groups of domestic firms. These groups are selected in the following ways:

- for the absorptive capability model: we classify domestic firms according to their absorptive capability into two groups: (a) those with high absorptive capacity and (b) those with low absorptive capacity. The distinction is made by using all the indicators of technological activity discussed in Section 5.2. The median value of each indicator is used to distinguish between 'high' and 'low'[xi];

- for the industry model: we group domestic firms according to the technological intensity of the industry in which they operate into four groups using the OECD classification of industries;

- for the subsidiary-centered model: we distinguish domestic firms according to the technological activity of the subsidiaries in their five-digit sub-industry – the 'space' of connection between subsidiaries and domestic firms, where horizontal spillovers are supposed to take place – into two types: (a) those with a relatively high intensity of technological activity on the part of subsidiaries and (b) those with a low intensity of technological activity on the part of subsidiaries. The classification is done in two steps: (1) we first add all subsidiaries' technological expenditures (or human resources destined for technological activities) per industry (five digits, measured using the indicators explained in

Section 5.2); (2) we then use the median to distinguish each five-digit sub-industry into two types: those with 'high' or 'low' intensity of technological activity by subsidiaries[xii].

6. Results

6.1 Spillovers in the original 'pipeline model'

Table 1 shows the results of our estimations for the pipeline model. These suggest that MNCs' operations had a positive effect on domestic firms in general in Brazil during the period analyzed. However, the coefficient and the significance level are very low. Next, we examine whether this is because we have failed to take account of differences between domestic firms in their ability to absorb the superior technology which, according to the pipeline model, must have been transferred by MNCs to their subsidiaries in Brazil.

TABLE 1 ABOUT HERE

6.2 The 'absorptive capability' model

Table 2 shows the results of our estimation of spillover effects in the absorptive capability model. Strikingly, we found that only two results are significant, and these run in the contrary direction to that expected by the absorptive capability model. While domestic firms with relatively higher expenditures in R&D do not enjoy positive spillovers, domestic firms with low R&D expenditures do enjoy positive effects. Something similar happens with expenditures for setting up innovations[xiii].

TABLE 2 ABOUT HERE

From these results, we cannot claim to have found support for the absorptive capability model. On the contrary, our results suggest that the inverse association between domestic firms' capability and spillovers might hold in Brazil, providing support to views prevalent in early studies about the impact of FDI (see, for instance, Findlay, 1978) and recent empirical studies (see, for instance, Haskel *et al.* 2002 and Gonçalves, 2005), which found that the higher the technology gap between subsidiaries and domestic firms, the higher the effect of FDI, because the opportunities for learning are higher as well.

6.3 The 'industry' model

According to this model the types of industry with relatively high/low levels of R&D intensity (and associated innovative activities) in advanced economies would have correspondingly high/low levels of innovative activity when they are relocated, via FDI, into middle-income economies like Brazil, and would therefore have a higher/lower potential for spillover effects.

To examine the importance of this model, we use the OECD classification of industries. The results are truly interesting. It is striking that the only significant positive effect appears in activities classified as medium low-tech. This suggests that in Brazil the technological characteristics of industries seem to affect the existence, direction and significance of spillover effects associated with FDI. Nevertheless, they do so in a more complex and unexpected way than is commonly presumed. The degree to which industries in the MNCs' country of origin are

technology intensive does not appear to be important. What seems to matter is how technology intensive the industries in the host country are. The next section explores the importance of a model that aims to incorporate these local influences by exploring an alternative source of heterogeneity on the supply side of spillover effects: subsidiaries' own knowledge-creating and knowledge-accumulating activities in the host economy.

TABLE 3 ABOUT HERE

6.4 Testing the importance of the 'subsidiary-centered model'

In this section we test the subsidiary-centered model by using a battery of specifications incorporating measures of *local* knowledge creation and knowledge accumulation by MNC subsidiaries. An array of strong, positive and significant results is generated.

Table 4 shows the sign and significance of technology spillovers for two types of domestic firms: (a) those located in five-digit sub-industries where foreign subsidiaries are 'technologically active' with respect to the indicators in the rows, and (b) those located in five-digit sub-industries where subsidiaries are 'technologically passive' with respect to the same indicators. It is striking that there are significant results with appropriate signs for all indicators.

For instance, R&D activities carried out by subsidiaries seem to be an important local driver for technology spillovers. When subsidiaries had relatively high expenditure on R&D, positive and significant spillovers were experienced by domestic firms. In contrast, domestic firms located in

industries where subsidiaries spent little on R&D experienced ‘negative spillovers’, though this last result is not significant. Something similar happens with set up innovation expenditures and R&D staff, both of which seem to be important sources of spillover effects for domestic firms.

TABLE 4 ABOUT HERE

The significance level is lower for expenditures in marketing, innovation-related training and investment in capital goods; nevertheless, the pattern is replicated. High levels of subsidiary investment are positively and significantly associated with positive spillovers to domestic firms. On the contrary, however, lower investments of subsidiaries are associated with non significant effects.

Concerning the relative importance of different kinds of technological efforts on the part of subsidiaries, it is interesting to note that the expenditures of subsidiaries that are more directly connected with the creation of new things, e.g. R&D expenditures, R&D staff and expenditures on setting up innovations, are stronger drivers of spillover effects than the other types of technology expenditures. This might be a reflection of the ‘high’ value that these types of creative activities may have in host countries like Brazil, where creative or innovative activity by firms is rarer than exploitative activities. Previous studies by De Araújo (2004) in Brazil[xiv] and by Marin and Sasidharan (2008) in India provide support for this idea.

8. Conclusions

This paper examined the dominant views about the mechanisms underlying FDI-related spillover effects in industrializing countries. We argued that the 'centrally driven perspective' that has dominated spillover studies for 40 years no longer provides a useful framework with which to explore the possibility of spillovers for two reasons: (1) it does not take account of recent theorizing from MNC literature about how MNCs actually operate and 2) it has failed to explain the existence/absence of spillover effects. The paper then proposed an alternative view. This alternative, drawing on recent MNC theory, focuses on the role of subsidiaries' own technological behavior. We refer to this as a ***'subsidiary-centered'*** model of spillover effects.

Our empirical exploration supported the importance of this alternative approach in the case of Brazil. We found a sharp contrast between the four approaches that we undertook in order to estimate spillover effects in association with FDI. The methods used in sub-sections 6.1, 6.2 and 6.3, based on underlying models of a process that is centrally driven by the transfer of technology from parent firms, yielded no evidence of spillover effects. We did not find significant results within the original pipeline model, and this changed very little when that model was augmented by consideration of the absorptive capability of domestic firms. Nor did it change when the effect of technological intensity of industries was examined. In contrast, when in Section 6.4 we tested a battery of models incorporating measures of localized knowledge creation and knowledge accumulation by MNC subsidiaries, an array of strong, positive and significant results was generated.

These results point clearly to the limitations of an MNC-centered perspective for exploring the possibility of spillovers in association with MNCs, and they highlight the potential benefits of

considering different aspects of subsidiary heterogeneity to identify situations that create positive effects. Furthermore, they highlight the importance of a new area of research questioning, related to the reasons for variability in the technological activity or innovativeness of MNC subsidiaries in developing economies. Innovative activity in subsidiaries in advanced contexts has been extensively researched in association with the more flexible approaches of MNCs discussed in Section 3. However, the literature has only very recently started to explore innovation and the reasons for variability of innovation in subsidiaries in less advanced contexts (Ariffin and Bell, 1999; Ariffin and Figueiredo, 2006; Consoni and Quadros, 2006; Marin and Bell, 2005; Giuliani and Marin, 2007). In consequence, our understanding of the circumstances favoring innovation in subsidiaries when they are localized in developing countries is still limited.

Finally, our results have important policy implications. They raise questions about the effectiveness of costly policies that, justified largely in terms of the spillovers to be achieved, seek simply to attract FDI regardless of the innovative activities that are likely to be undertaken by the subsidiaries that are established. They also raise questions with respect to policy views that recommend focusing on "attracting good-quality FDI" as the only policy tool for extracting benefits from MNCs (see for instance Mortimore and Vergara, 2007). We show that what is important in order for spillovers to take place is not so much the quantity or the kind of FDI to be attracted but, rather, the question of what subsidiaries *actually do* once they have been established or acquired. Policies towards MNCs would thus concentrate on identifying/designing policies that influence subsidiaries' technological and innovative behavior once they have been established within the host economy. Although fragments of evidence exist with regard to the kinds of policies that might be effective, our understanding of the possibilities for policy in this

area remains limited. More research needs to be conducted to identify different options and their effectiveness.

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Table 1: FDI spillovers in the 'Pipeline Model'[1] – Brazil 1998-2005

	FDI coefficient and t value
Spillover Effects	
Lagged Δ FDI - Labour	0.0018
	(1.75)*
Control Variables	
Δ Concentration	-0.73
	(-3.19)***
Δ Import Penetration	0.0046
	(1.63)
Number of observations and R2	32320
	9%

Source: own calculations based on IBGE/PIA (pooled data 1996-2005) and the IBGE/PINTEC 2003-2005
Notes: (1) The dependent variable is the change in TFP (expressed as a natural logarithm) of a Brazilian firm *i* at time *t*, derived from sector-specific production functions estimated using the Levinsohn-Petrin approach. All specifications include a constant, year and industry fixed effect. Standard errors corrected for clustering for industry-year combinations are reported in parentheses. * denotes significance at the 10% level, ** at the 5% level, *** at the 1% level. (2) Here we report only the results based on Levinsohn and Petrin; results obtained with ordinary least squares (OLS) and fixed effects are very similar, the sign and significance are the same. They are available from the authors on request. (3) For the purposes of brevity we show only the coefficients and significance levels for the FDI variable in the estimation models. The coefficients and significance levels for all the other variables included in each regression are available on request from the authors.

Table 2: FDI spillovers in the 'Absorptive Capability Model'[1] – Brazil 1998-2005

When domestic firms' absorptive capabilities are defined as High or Low with respect to the following:	Sign and significance of the estimation of FDI spillovers for domestic firms when their absorptive capabilities are:[1]			
	High		Low	
	FDI coefficient and t value	N and R2	FDI coefficient and t value	N and R2
(1) Investments in disembodied knowledge				
(1.1) R&D expenditures	-0.00081	7664	0.029	24656
	(-0.05)	(11%)	(1.83)*	(9%)
(1.2) Other investments in disembodied knowledge	0.034	2197	0.015	30123
	(1.42)	(10%)	(1.43)	(9%)
(1.3) Set up innovation expenditures	-0.14	7001	0.028	25319
	(-0.83)	(10%)	(2.16)*	(8%)
(1.4) Expenditures on marketing	-0.015	5732	-0.33	26588
	(-0.97)	(12%)	(-0.75)	9%
(2) Human Capital				
(2.1) R&D staff	-0.13	833	0.020	31487
	(-0.84)	(3%)	(1.78)*	(9%)
(2.2) Innovation-related training	0.0068	5920	0.021	26400
	(0.34)	(9%)	(1.4)	(9%)
(3) Investments in capital-embodied technology				
(3.3) Capital goods for innovations	0.018	12429	0.020	19891
	(1.09)	(9%)	(1.15)	9%

Source: own calculations based on IBGE/PIA (pooled data 1996-2005) and the IBGE/PINTEC 2003-2005
Notes: (1) The dependent variable is the change in TFP (expressed as a natural logarithm) of a Brazilian firm *i* at time *t*, derived from sector-specific production functions estimated using the Levinsohn-Petrin approach. All specifications include a constant, year and industry fixed effect. Standard errors corrected for clustering for industry-year combinations are reported in parentheses. * denotes significance at 10% level, ** at the 5% level, *** at the 1% level. (2) Here we report only the results based on Levinsohn and Petrin; results obtained with ordinary least squares (OLS) and fixed effects are very similar, the sign and significance are the same. They are available from the authors on request. (3) For the purposes of brevity we show only the coefficients and significance levels for the FDI variable in the estimation models. The coefficients and significance levels for all the other variables included in each regression are available on request from the authors.

Table 3: FDI spillovers in the 'Industry Model': using OECD classification [1] – Brazil 1998-2005

When industries are classified by technological intensity according to:	Sign and significance of the estimation of FDI spillovers for domestic firms[2]: FDI coefficient and t value	
(a.1) High tech	-0.016	3233
	(-0.43)	(17%)
(a.2) Medium High Tech	0.017	6281
	(0.82)	(19%)
(a.3) Medium Low Tech	0.06	7186
	(3.37)***	(15%)
(a.4) Low Tech	0.0068	15620
	(0.5)	(6%)

Source: own calculations based on IBGE/PIA (pooled data 1996-2005) and the IBGE/PINTEC 2003-2005
Notes: (1) The dependent variable is the change in TFP (expressed as a natural logarithm) of a Brazilian firm *i* at time *t*, derived from sector-specific production functions estimated using the Levinsohn-Petrin approach. All specifications include a constant, year and industry fixed effect. Standard errors corrected for clustering for industry-year combinations are reported in parentheses. * denotes significance at 10% level, ** at the 5% level, *** at the 1% level. (2) Here we report only the results based on Levinsohn and Petrin; results obtained with ordinary least squares (OLS) and fixed effects are very similar, the sign and significance are the same. They are available from the authors on request. (3) For the purposes of brevity we show only the coefficients and significance levels for the FDI variable in the estimation models. The coefficients and significance levels for all the other variables included in each regression are available on request from the authors.

Table 4: FDI spillovers in the 'Subsidiary-driven Model' – Brazil 1998-2005

When the activities are classified as active or passive with respect to the following aspects of subsidiaries' behaviour:	Sign and significance of the estimation of FDI spillovers for domestic firms in activities where subsidiaries are[1]:			
	Technologically Active		Technologically Passive	
	FDI coefficient and t value	N and R2	FDI coefficient and t value	N and R2
(1) Investments in disembodied technology				
(1.1) R&D expenditures	0.04	14605	-0.035	17715
	(3.38)***	(9%)	(-1.26)	(9%)
(1.2) Other investments in disembodied knowledge	0.06	7707	0.0024	24613
	(2.19)**	(12%)	(0.11)	(8%)
(1.3) Set up innovation expenditures	0.038	14595	0.013	17725
	(2.88)***	(9%)	(0.36)	(9%)
(1.4) Expenditures on marketing	0.053	12443	0.29	19877
	(2.75)**	(9%)	(1.05)	(9%)
(2) Human Capital				
(2.1) R&D staff	0.067	14078	-0.048	18242
	(3.43)***	(10%)	(-1.58)	(9%)
(2.2) Innovation-related training	0.033	13589	-0.002	18731
	(2.44)**	(10%)	(-0.08)	(9%)
(3) Investments in capital-embodied technology				
(3.3) Capital good for innovations	0.036	14772	-0.058	14863
	(2.75)**	(10%)	(-1.53)	(9%)

Source: own calculations based on IBGE/PIA (pooled data 1996-2005) and the IBGE/PINTEC 1998-2005
Notes: (1) The dependent variable is the change in TFP (expressed as a natural logarithm) of a Brazilian firm *i* at time *t*, derived from sector-specific production functions estimated using the Levinsohn-Petrin approach. All specifications include a constant, year and industry fixed effect. Standard errors corrected for clustering for industry-year combinations are reported in parentheses. * denotes significance at 10% level, ** at the 5% level, *** at the 1% level. (2) Here we report only the results based on Levinsohn and Petrin; results obtained with ordinary least squares (OLS) and fixed effects are very similar, the sign and significance are the same. They are available from the authors on request. (3) For the purposes of brevity we show only the coefficients and significance levels for the FDI variable in the estimation models. The coefficients and significance levels for all the other variables included in each regression are available on request from the authors.

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Notes

[i] By way of an example, of the 60 studies reviewed by Crespo and Fontouro (2007) only 12 identified positive effects, 12 found negative effects, and 31 cases found insignificant effects.

[ii] Both studies corroborated their arguments in the case of England. However, in the case of India, Marin and Sasidharan (2008), focusing on subsidiaries' activities rather than on FDI motivation, found that creative subsidiaries –which could be associated with FDI motivated by sourcing – generate positive effects, while competence-exploiting subsidiaries – which could be associated with FDI motivated by exploiting – generated negative effects.

[iii] Exceptions are Todo and Miyamoto (2002); Castellani and Zanffei (2005); Marin and Bell (2006) and Marin and Sasidharan (2008).

[iv] For instance, Furtado (2004:8) points to the significance of the capability-building process within MNC subsidiaries in the metal-mechanic complex in Brazil, which helped them to accumulate their own assets and develop their 'own identities'.

[v] Data from the Brazilian Central Bank – Bacen, quoted by Costa (2006).

[vi] Monetary values were deflated by the sectoral IPA-OG, calculated by Fundação Getulio Vargas (FGV).

[vii] We also used output participation and the results did not change. They are available upon request from the authors.

[viii] This is important because, as noted earlier, during the period analyzed important pro-market reforms were introduced and developed in Brazil.

[ix] However, we cannot rule out the possibility of spurious correlation if there are industry characteristics that change over time and affect the pattern of FDI.

[x] This also controls for other factors that, even when they are not fixed over time, might be roughly constant over a four-year period, such as level of education or regional policies.

[xi] Sensitiveness tests were run using top and low quartiles, and the results did not change.

[xii] Sensitiveness tests were run using top and low quartiles, and the results did not change.

[xiii] Similar results were identified in a previous study in Brazil by Gonçalves (2005) for the period 1997-2000.

[xiv] De Araújo (2004) found that R&D efforts by MNC subsidiaries have a positive impact on the probability of domestic firms investing in R&D.